PNS SCHOOL OF ENGINEERING & TECHNOLOGY

Nishamani Vihar, Marshaghai, Kendrapara

LECTURE NOTES
ON
ESTIMATING & COSTING ENGINEERING

DEPARTMENT OF CIVIL ENGINEERING

5TH SEMESTER

PREPARED BY

ER. GAYATREE SAHOO

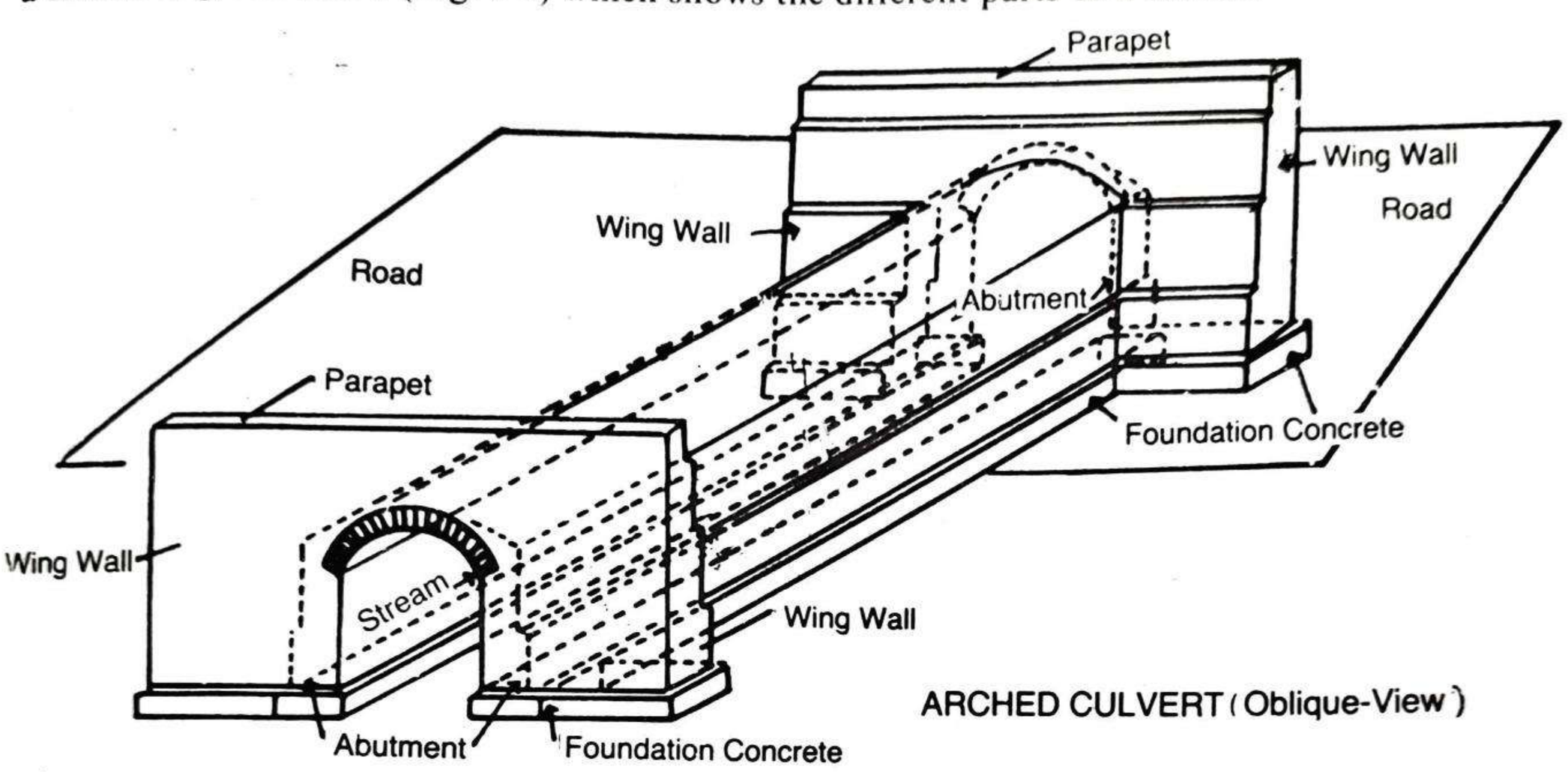
LECTURER IN CIVIL ENGINEERING

CHAPTER 8

CULVERTS, BRIDGES, WELLS

CULVERTS

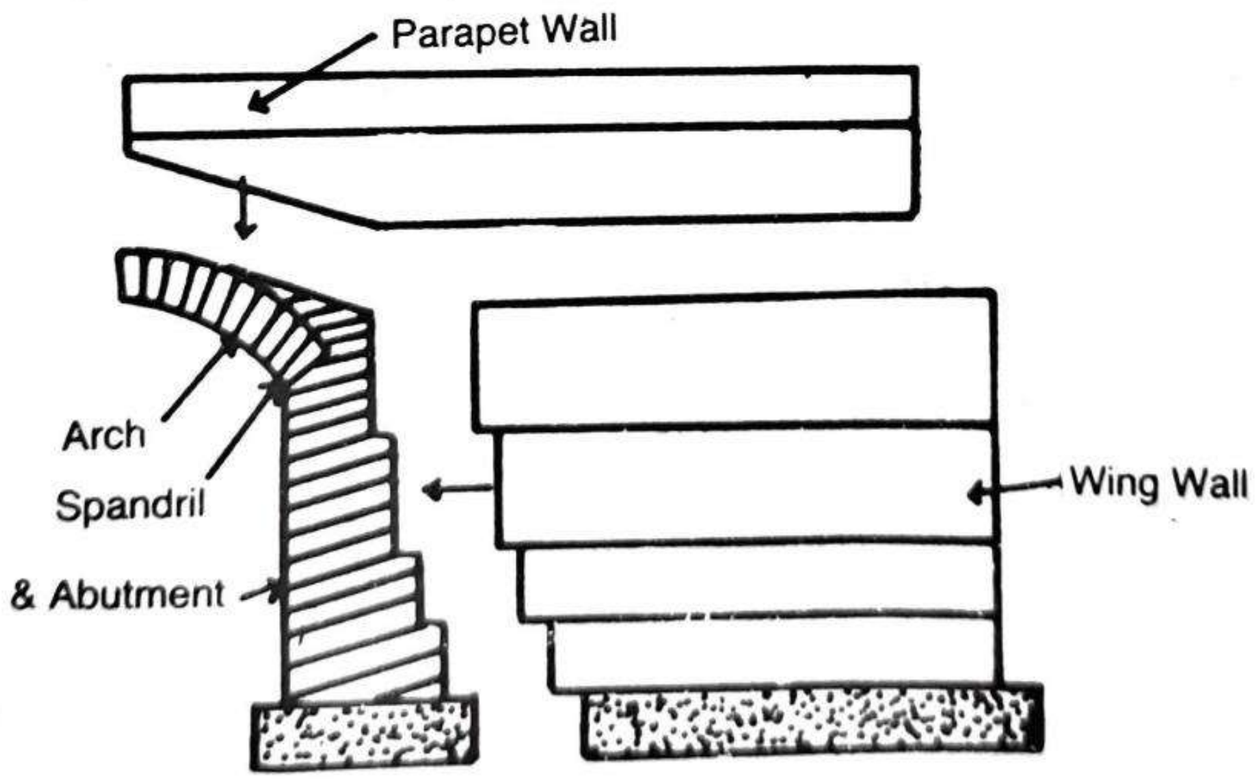
Estimating of bridges and culverts are simpler than that of building, but the beginners find building easier because they are more familiar with the parts of building than they are with those of bridges and culverts. An arched culvert consists of abutments, wing walls, arch, parapets and necessary foundation. Floor and curtain walls may or may not be provided depending on the nature of soil and velocity of flow. Exposed surfaces are usually finished with pointing. An oblique view of a culvert is given below (Fig. 8-1) which shows the different parts of a culvert.



ARCHED CULVERT (Oblique-View)

Fig. 8-1

For estimating, the different parts of the culvert should be considered separately. First the two abutments with foundations up to the springing level and then the portions of haunch or spandril above the springing level should be estimated. Then the four wing walls with foundation up to the haunch level should be taken up, and then the parapet walls should be estimated. Arch masonry should be calculated separately. Finishing work of the surfaces is taken up lastly.



DIFFERENT PARTS OF CULVERT

Fig. 8-2

R.C.C. SLAB CULVERTS - 1.5 METRE SPAN

Example 1. — Prepare a detailed estimate of a slab culvert of 1.50 metre span and 4.00 metre roadway from the given drawing (Fig. 8.5). The general specifications are as follows :—

Foundation concrete shall be of cement concrete 1 : 3 : 6 with stone ballast and coarse sand. Masonry shall be of first class brickwork in 1 : 4 cement coarse sand mortar. Slab shall be of R.C.C. 1 : 2 : 4 with reinforcement as per drawing. Exposed surface of brick masonry shall be cement pointed 1 : 2. Road shall be provided with 10 cm thick wearing coat of 1 : 2 : 4 cement concrete. Assume suitable rates.

R.C.C. SLAB CULVERT 1.50 m SPAN with standard modular bricks

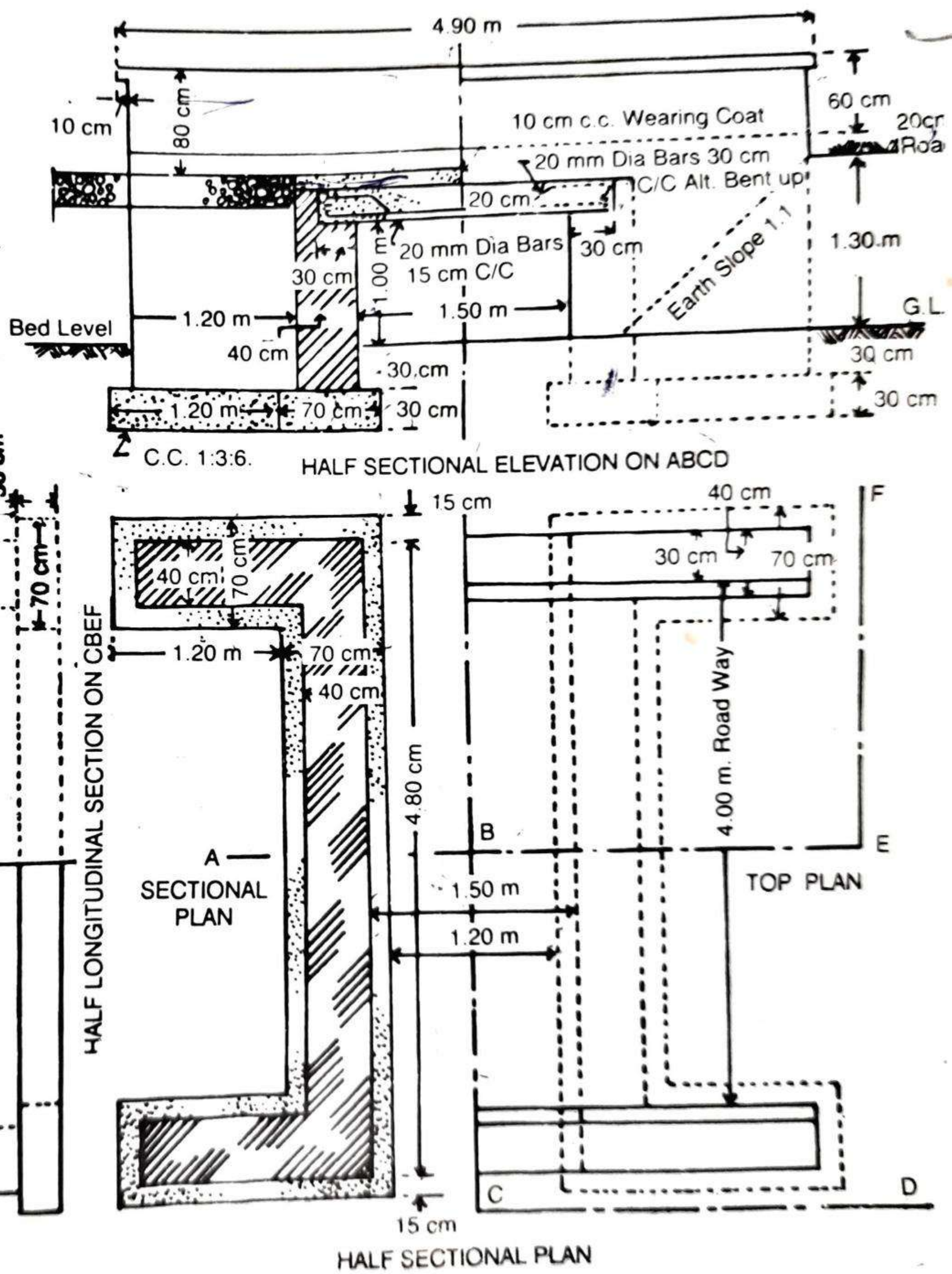


Fig. 8-5

Details of Measurement and Calculation of Quantities (Ex. 1)

Item No.	Particulars of items of works	No.	Length m	Breadth m	Height or Depth m	Quantity	Explanatory notes
1.	**Earthwork in excavation** in foundation —						
	Abutments ...	2	5.10	0.70	0.60	4.28	
	Wings walls ...	4	1.20	0.70	0.60	2.02	
					Total	6.30	cu m
2.	**Cement concrete** 1:3:6 in foundation with stone ballast— Abutments ...	2	5.10	0.70	0.30	2.14	½ of earthwork in excavation in item 1.
	Wings walls ...	4	1.20	0.70	0.30	1.01	
					Total	3.15	cu m
3.	**I-class brickwork in 1 : 4** cement mortar—						
	Abutments ...	2	4.80	0.40	1.50	5.76	Up to top of R.C.C. slab.
	Wing walls ...	4	1.20	0.40	1.50	2.88	
	Parapets up to kerb ...	2	4.70	0.40	0.30	1.13	Above R.C.C. slab up to kerb.
	Parapets above kerb ..	2	4.70	0.30	0.50	1.41	Above kerb excluding coping.
	Parapet coping ...	2	4.90	0.40	0.10	0.39	
					Total	11.57	
	Deduct— Bearing of R.C.C. slab in abutment	2	4.80	0.30	0.20	0.57	
4.	**R.C.C. work 1 : 2 : 4 in slab** excluding steel and its bending but including centering shuttering and binding			Net	Total	11.00	cu m
	steel	1	4.80	2.10	0.20	2.016 cu m	No deduction for volume of steel.
5.	**Steel bars including bending in R.C.C. work—**						
	20 mm dia. bars— Main straight bars 30 cm c/c ...	17	2.38	—	—	40.46 cu m	L=2.10—2 side covers + 2 hooks = 2.10— (2×4 cm)+(18× 20 mm) = 2.38 m
	(No.= $\frac{4.80}{.30}$ + 1 = 17)						

	Particulars of items of works	No.	Length m	Breadth m	Height or Depth m	Quantity	Explanatory notes
	Main bent up bars 30 cm c/c ... (No. = $\frac{4.80}{.30}$ = 16)	16	2.54	—	—	40.64 m	Adding one depth, 16 cm for two bent ups L=2.38+.16 = 2.54 m
			Total	81.10 m	@ 2.47	kg m= 200.32kg	
	10 mm Dia. bars— Distributing bottom bars 25 cm c/c ...	9	4.90	—	—	44.10 m	L=4.80—2 end covers +3 hooks =4.80— (2×4 cm) + (18× 10mm)= 4.90 m
	Distributing top bars	4	4.90	—	—	19.60 m	
	To	tal	63.70 m	@.62 kg	=	39.49 kg	
			Total	of	steel	239.81 kg	2.398 quintal
6.	**Cement concrete 1:2:4 wearing coat** ...	1	4.00	2.30	0.10	0.92 cu m	In between parapets
7.	**Cement pointing 1:2 in walls—**						
	Face wall from 10 cm below G.L. up to bottom of coping	2	4.70	—	2.10	19.74	
	Inner side of parapet excluding coping	2	4.70	—	0.80	7.52	Ht.=(20+10+50) =0.80 mm
	Coping (inner edge, top, outer edge and outer and side) ...	2	4.90	0.70	—	6.86	B=(10+40+10+10) cm = 0.70 m
	Ends of parapet ...	4	—	0.40	0.20	0.32	Up to kerb.
	Ends of parapet ...	4	—	0.30	0.50	0.60	Above kerb.
	Ends of coping ...	4	—	0.40	0.20	0.32	Edge and under side.
					Total	35.36	
	Deduct— Rectangular opening	2	1.50		1.30	3.90	Including 10 cm below G.L. and edge of R.C.C. slab.
	Triangular portion below earth slope	2	(½×1.30	×1.30)		1.69	
				Total of	deductio	n 5.59	
				Net	Total	29.77	sq m

SLAB CULVERT

ABSTRACT OF ESTIMATED COST (Ex. 1)

Item No.	Particulars of items of work	Quantity	Unit	Rate Rs. P.	Per	Amount Rs. P.
1.	Earthwork in excavation in foundation ...	6.30	cu m	350.00	% cu m	22.05
2.	Cement concrete 1 : 3 : 6 in foundation with stone ballast ..	3.15	cu m	400.00	cu m	1260.00
3.	I-class brickwork in 1 : 4 cement mortar	11.00	cu m	365.00	cu m	4015.00
4.	R.C.C. work 1 : 2 : 4 in slab excluding steel and its bending but including centering. shuttering and binding steel ...	2.016	cu m	775.00	cu m	1562.40
5.	Steel bars including bending in R.C.C. work ...	2.398	quintal	515.00	quintal	1234.97
6.	Cement concrete 1 : 2 : 4 in wearing coat	0.92	cu m	450.00	cu m	414.00
7.	Cement pointing 1 : 2 in wall ...	29.77	sq m	5.60	sq m	166.71
					Total ...	8675.13
	Add 5%-(3% for Contingencies and 2% for Workcharged Establishment) ...					433.75
					Grand Total ...	9108.88

Rate per running metre of span = $\frac{\text{Total Cost}}{\text{span}} = \frac{9108.88}{1.5}$ = Rs. 6072.58 per metre.

Example 7.—Prepare a detailed estimate of Hume pipe Culvert of three pipes each of 60 cm diameter from the given plan and elevations Fig. 8-14. Foundation concrete shall be of 1 : 4 : 8 cement concrete and brickwork shall be of first class in 1 : 6 cement sand mortar. Exposed surfaces shall be pointed with 1 : 2 cement sand mortar.

Assume suitable rates.

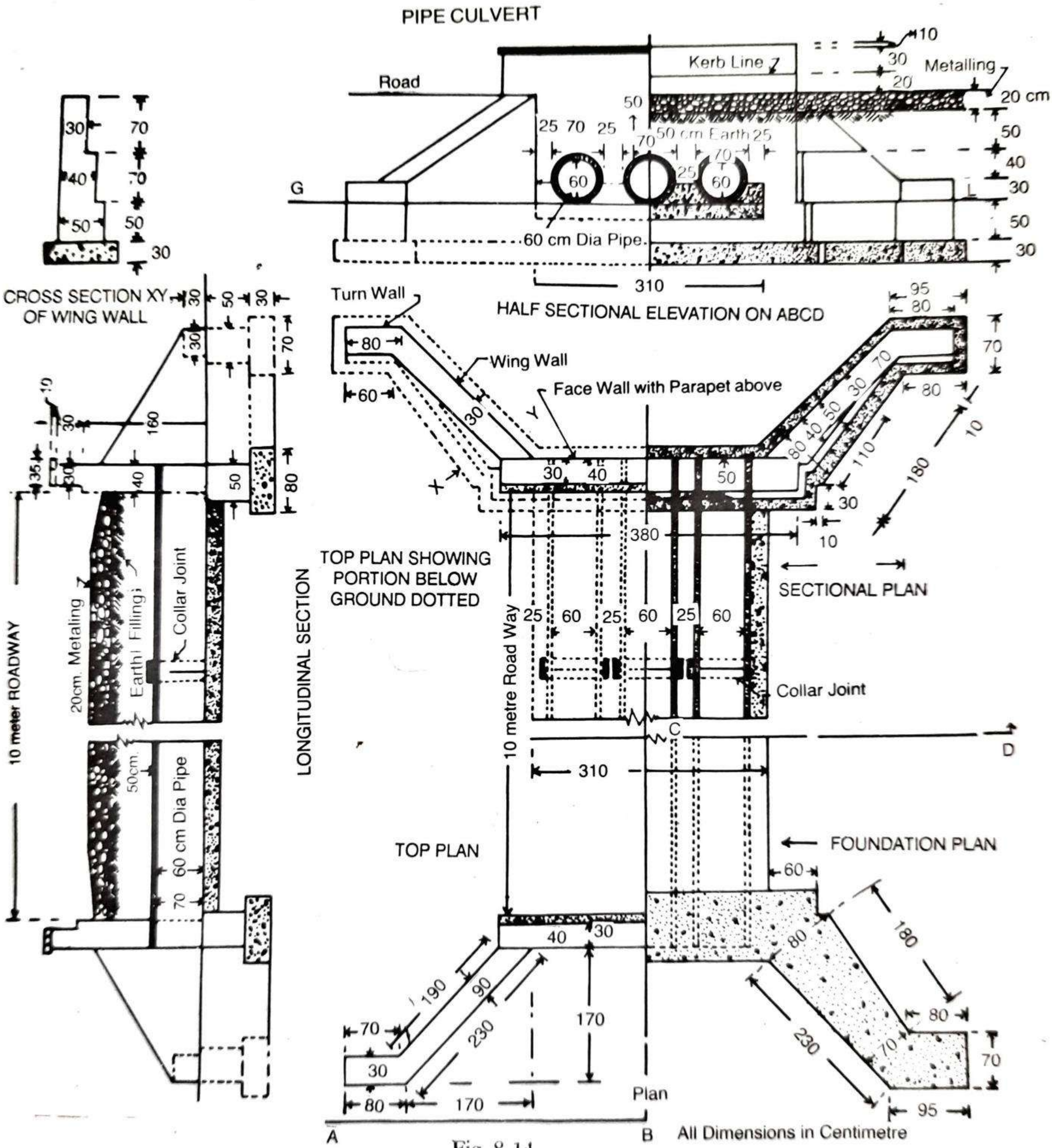


Fig. 8-14

Details of Measurement and Calculation of Quantities (Ex. 7)

Item No.	Particulars of items	No.	Length m	Breadth m	Height or Depth m	Quantity	Explanatory notes
1	Earthwork in excavation in foundation—						
	Face walls ...	2	3.10	.80	.80	3.97	
	Wing walls inclined portion ...	4	$\frac{2.3+1.8}{2}$	$\frac{.8+.7}{2}$	.80	4.92	Average length and average breadth.
	Wing walls triangular corner ...	4	(½×.6×.8)		.80	0.77	Area of triangle.
	Turn walls ...	4	$\frac{.95+.80}{2}$	.70	.80	1.96	Average length.
	Under pipe ...	1	9.80	3.10	.15	4.56	
					Total	16.18 cu m	
2	Cement concrete 1 : 4 : 8 in foundation—						
	Face walls ...	2	3.10	.80	.30	1.49	
	Wing walls inclined portion ...	4	$\frac{2.3+1.8}{2}$	$\frac{.80+.70}{2}$	.30	1.85	
	Wing walls inclined portion ...	4	(½×.6×.8)		.30	0.29	
	Turn walls ...	4	$\frac{.95+.80}{2}$	.70	.30	0.74	
	Upper pipe and in between pipe up to half height ...	1	9.80	3.10	.50	15.19	Thickness=$15+\frac{70}{2}$
					Total	19.56	=50 cm = .50 m
	Deduct half of pipes ...	3	9.80×½	$\frac{\pi\times.7^2}{4}$		5.66	
					Total	13.90	cu m
3	First class brickwork in 1:6 cement sand mortar—						
	Face walls—						
	Footing—50 cm breadth	2	4.00	.50	.50	2.00	Breadth means thickness of wall.
	Above footing 40 cm breadth ...	2	3.80	.40	1.60	4.86	
					C.O.	6.86	

Item No.	Particulars of items	No.	Length • m	Breadth m	Ht. or Depth m	Quantity	Explanatory notes
					B.F.	6.86	
	Parapet—30 cm breadth	2	3.80	.30	.30	0.68	
	Coping—35 cm breadth	2	4.00	.35	.10	0.28	
	Wing walls—						
	1st step—40 cm breadth	4	1.10	$\frac{.5+0}{2}$	.50	0.55	
	2nd step—40 cm breadth—						
	(*i*) Straight portion ...	4	1.80	.40	.30	0.86	
	(*ii*) Sloping portion ...	4	1.80	.40	$\frac{.40+.0}{2}$	0.58	Average height.
	3rd step—30 cm breadth	4	1.90	.30	$\frac{.70+0}{2}$	0.80	Average height.
	Turn wall—40 cm breadth	4	$\frac{.8+.7}{2}$	.40	.50	0.60	
	Turn wall—30 cm breadth ...	4	$\frac{.80+.75}{2}$	.30	.30	0.28	
					Total	11.49	cu m
4	Cement pointing 1 : 2 in exposec surfaces above G.L.—						
	Face walls outer sides ...	2	3.10	—	1.40	8.68	Up to road level
	Face wall parapet outer side	2	3.80	—	.65	4.94	Above road level including coping. Ht. = 20+30+10 +5=65 cm =.65 m
	Parapet inner faces ...	2	3.80	—	.70	5.32	Including kerb offset of 10 cm
	Wing walls vertical face	4	2.30	—	$\frac{1.40+.50}{2}$	8.74	Average height.
	Wing walls top ...	4	2.30	.30	—	2.76	
	Turn walls vertical face three sides ...	4	1.80	—	.30	2.16	L = Perimeter = 80 + 30 + 70 = 180 cu m = 1.80 m
	Turn walls top ...	4	$\frac{.8+.7}{2}$	.30	—	0.90	
					Total	33.50	sq m
5	Hume pipe heavy type 60 cm dia. including collar joint ...	3	10.80	—	—	32.40	L = 10 + .4 + .4 = 10.8 m

Abstract of Estimated Cost (Ex. 7)

1.	Earthwork in excavation in foundation ...	16.18 cu m @ Rs. 350.00% cu m = Rs.	56.63
2.	Cement concrete 1 : 4 : 8 in foundation brick ballast ...	13.90 cu m @ Rs. 300.00 per cu m = Rs.	4170.00
3.	First class brickwork in 1 : 6 cement mortar ...	11.49 cu m @ Rs. 340.00 per cu m = Rs.	3906.60
4.	Cement pointing 1 : 2 in exposed surfaces ...	33.50 cu m @ Rs. 5.60 per sq m = Rs.	187.60
5.	Hume pipe heavy type 60 cm dia. including collar joint ...	32.40 m @ Rs. 125.00 per m = Rs.	4050.00
		Total .... Rs.	12370.83
	Add 5% for Contingencies and Workcharged Establishment	... Rs.	618.54
		Grand Total ... Rs.	12989.37

STEEL BRIDGES

DRAINAGE SYPHON ACROSS A MINOR

Example 7. —Prepare a detailed estimate of a Drainage Syphon across a minor from the given drawing, Figs. 9-8 and 9-9.

Foundation concrete shall be of 1 : 4 : 8 cement concrete with brick ballast. All brickwork shall be of 1 : 4 cement mortar. Exposed surfaces of brickwork shall be struck pointed with 1 : 2 cement mortar. Brick pitching shall be of dry brick with straight over burnt bricks.

Assume suitable rates for the different items of work.

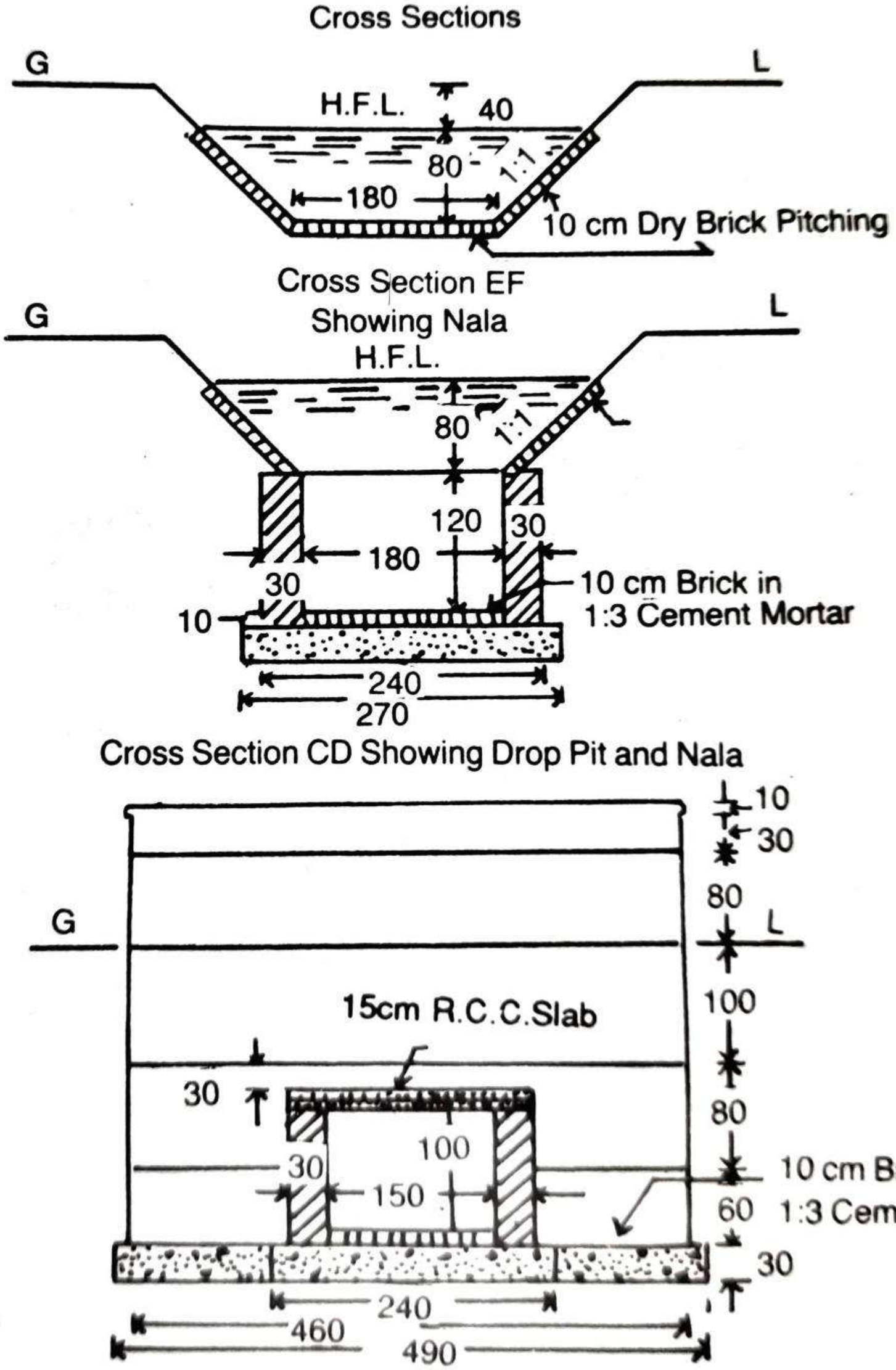


Fig. 9-8

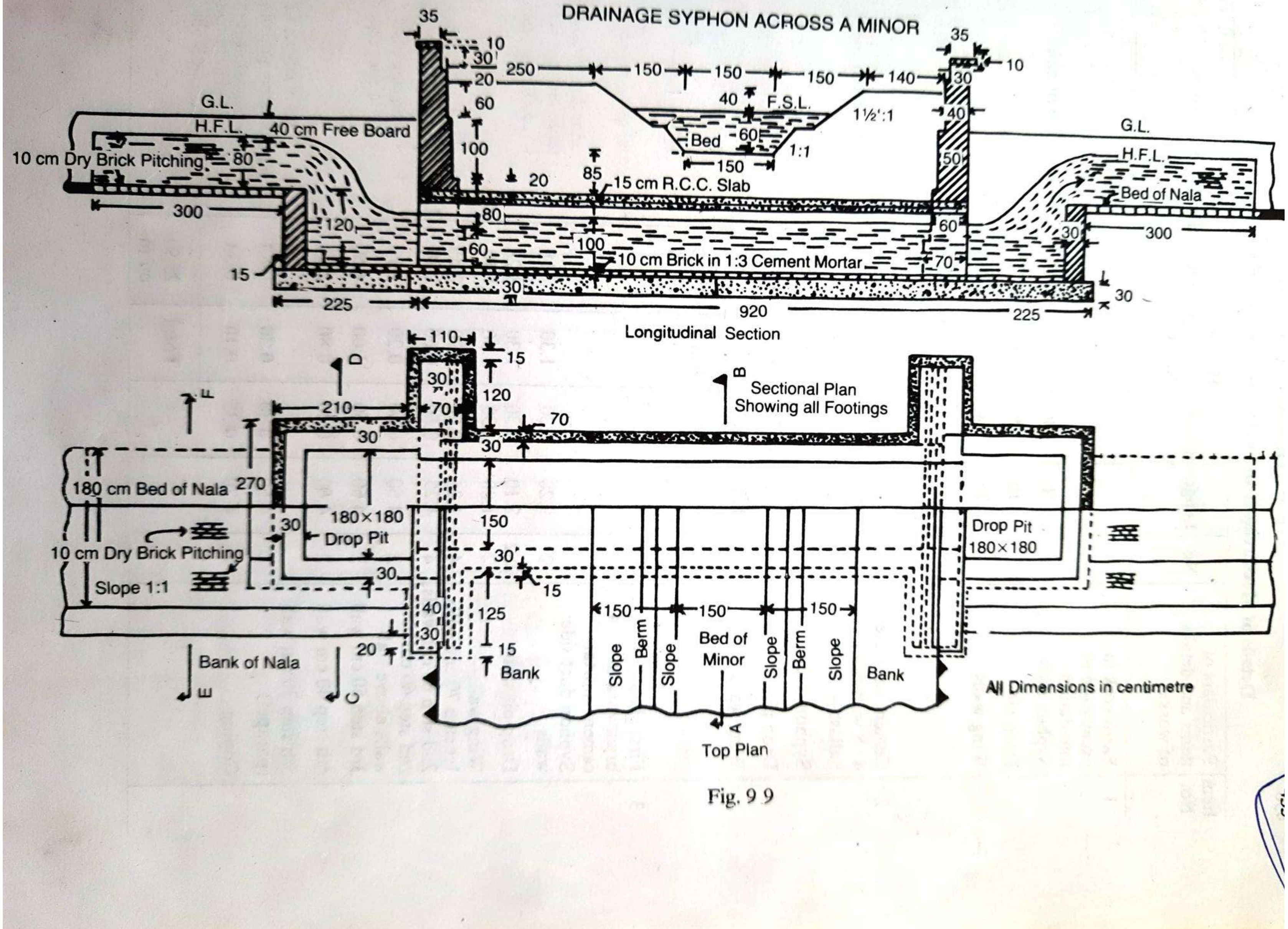


Fig. 9 9

Details of Measurement and Calculation of Quantities (Ex. 7)

Item No.	Particulars of items and details of works	No.	Length m	Breadth m	Height or Depth m	Quantity	Explanatory notes
1	Earthwork in excavation in foundation—						
	Syphon duct ...	1	9.50	2.40	1.60	36.48	*For bed level of nala.*
	Drop pit ...	2	2.10	2.70	1.60	18.14	
	Wing walls ...	4	1.25	1.10	1.60	8.80	
					Total	63.42 cu m	
2	Cement concrete 1 : 4 : 8 with brick ballast—						
	Syphon duct ...	1	9.50	2.40	0.30	6.84	
	Drop pit ...	2	2.10	2.70	0.30	3.40	
	Wing walls ...	4	1.25	1.10	0.30	1.65	
					Total	11.89 cu m	
3	First class brickwork in 1 : 4 cement mortar—						
	Syphon duct side walls	2	9.20	0.30	1.30	7.18	
	Drop pit walls ...	2×2	2.10	0.30	1.30	3 28	
		2	1.80	.30	1.30	1.40	
	Wing walls—						
	1st step 70 cm walls	4	1.25	0.70	0.70	2.45	
	2nd step 60 cm walls	4	1.25	0.60	0.60	1.80	Upto top of slab.
	2nd step 60 cm walls above slab	2	4.60	0.60	0.20	1.10	
	3rd step 50 cm wall	2	4.60	0.50	1.00	4.60	
	4th step 40 cm wall	2	4.60	0.40	0.80	2.94	
	5th step 30 cm wall (parapet)	2	4.60	0.30	0.30	0.83	
	Coping	2	4.70	0.35	0.10	0.33	
					Total	25.91 cu m	

Item No.	Particulars of items and details of works	No.	Length m	Breadth m	Height or Depth m	Quantity	Explanatory notes
4	R.C.C. slab of syphon duct including steel reinforce-ment complete work	1	9.20	2.10	0.15	2.90 cu m	
5	10 cm thick brick floor in 1 : 3 cement mortar including 1 : 2 cement pointing —						
	Floor of syphon duct	1	9.20	1.50	—	13.80	
	Floor of drop pit ...	2	1.80	1.80	—	6.48	
					Total	20.28 sq m	
6	Cement struck pointing 1 : 2—						
	Syphon duct inner faces	2	9.20	—	1.00	18.40	
	Drop pit 3 vertical faces	2×3	1.80	—	1.20	12.96	
	Drop pit 3 top faces	2	5.70	—	0.30	3.42	L=2×180+210 =570 cm
	Parapet wall inner face top and outer face up to G.L.	2	4.60	—	2.30	21.16	Ht.=20+10+30+10 +35+10+5+110 =230 cm
	Outer face of wing wall above slab ...	2	1.80	—	1.20	4.32	
	Triangular portion of outer face of wing wall	2×2	(½×.8	×.8)	=	1.28	
					Total	61.54 sq m	
7	10 cm dry brick pitching with straight over burnt bricks—						*Thin piching, unit in area basis.*
	Bed of nala	2	3.00	1.80	—	10.80	*Up and down streams.*
	Side slopes of nala	2×2	3.00	1.13	—	13.56	*Sloping breadth=* $\sqrt{.8^2+.8^2}$=1.13 m
					Total	24.36 sq m	

Item No.	Particulars	Quantity	Unit	Rate Rs. P.	Per	Amount Rs. P.
1	Earthwork in excavation ...	63.42	cu m	350.00	% cu m	221.97
2	Cement concrete 1 : 4 : 8 with brick ballast ...	11.89	cu m	375.00	/ cu m	4458.75
3	First class brickwork in 1 : 4 cement mortar ...	25.91	cu m	365.00	/ cu m	9457.15
4	R.C.C. slab including steel reinforcement complete work ...	2.90	cu m	775.00	/ cu m	2247.50
5	10 cm thick brick floor in 1 : 3 cement mortar with 1 : 2 cement pointing ...	20.28	sq m	40.00	/ sq m	811.20
6	Cement struck pointing with 1 : 2 cement mortar in walls ...	61.54	sq m	5.60	/ sq m	344.62
7	10 cm dry brick pitching with straight over burnt brick ...	24.36	sq m	12.00	/sq m	292.32
					Total ...	17833.51
					Add 5% for Contingencies and Workcharged Establishment ...	891.68
					Grand Total ...	18725.19

FALL

Irrigation channels are given certain longitudinal slope to develop certain velocities depending on the nature of soil and silt content in water. Steeper longitudinal slope develops higher velocities causing scour in the bed of the channel. If the general ground has a steep slope and the channel is given a flatter slope, the channel may meet the ground level and further may move the ground level necessitating high bank. To obviate the difficulty, falls or drops are given in the channel at suitable points where it tends to go near or above the ground level. At falls masonry structures are constructed to prevent scouring and to confine and to direct the channel water along its course. Estimate of a small fall has been given in Example 8.

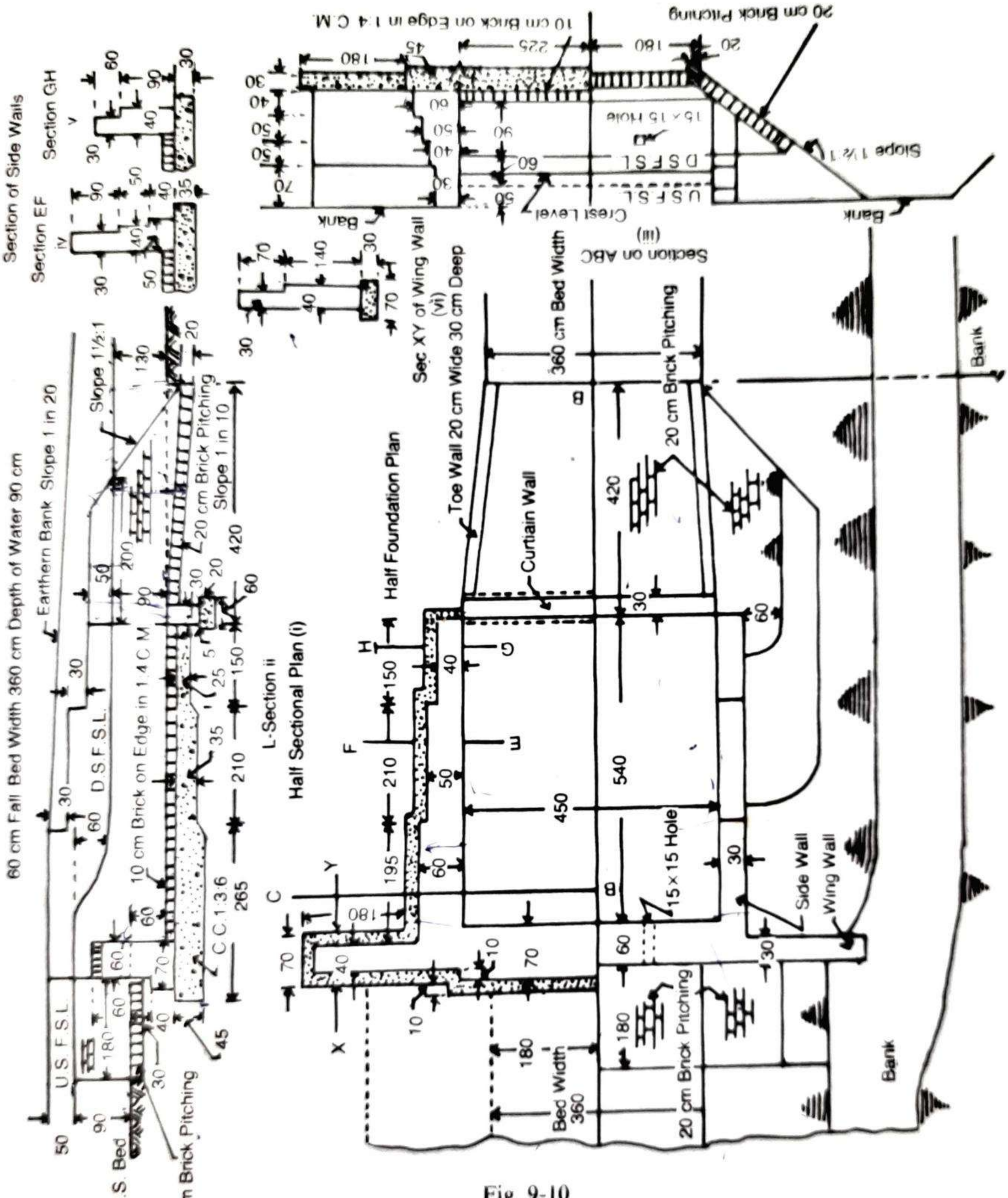


Fig. 9-10

ESTIMATE OF A 60 cm FALL

Example 8 — Prepare a detailed estimate of a 60 cm fall for a distributory of 360 cm bed width and 90 cm depth of water, from the drawing given (Fig. 9-10 page 441). Side slope of bank and channel are 1½ : 1. The general specifications are as follows :—

Foundation and apron concrete—Cement concrete 1 : 3 : 6 with stone ballast.
Masonry—All brickwork shall be of I-class in 1 : 4 cement mortar.
Pointing—All exposed surfaces shall be pointed with 1 : 4 cement and sand mortar.
Pitching—Pitching shall be of dry brick with straight over burnt bricks.
Rates—Assume suitable rates.

Details of Measurement and Calculation of Quantities (Ex. 8)

Item No.	Particulars of items and details of works	No.	Length m	Breadth m	Height or Depth m	Quantity	Explanatory notes
1	**Earthwork in excavation** Crest wall, side walls and floor (taken together)—						
	(i) ...	1	2.65	6.00	1.15	18.29	B=4.5+2×.6+2×.15 =6.00 m
	(ii) ...	1	2.10	5.80	1.05	12.79	B=4.5+2×.5+2×.15 =5.80 m
	(iii) ...	1	1.50	5.60	0.95	7.98	B=4.5+2×.4+2×.15 =5.60 m
	Wing walls beyond side walls ...	2	1.80	0.70	1.00	2.52	
	Curtain walls ...	1	4.50	0.60	1.20	3.24	
	Up stream pitching 20 cm depth—						
	Bed	1	1.80	3.60	0.20	1.30	
	Side slopes (up to F.S.L.)	2	1.80	1.62	0.20	1.17	Sloping breadth $=h\sqrt{s^2+1}$ $=.9\sqrt{(1\frac{1}{2}^2+1)}$ =1.62 m
	Down stream channel beyond curtain wall. trapezium section $(Bd+sd^2)\times L$ ...	(4.0	5×.8+1½	×.8²)	×3.90	=16.38	Average breadth $=\frac{4.5+3.6}{2}=4.05$ m Average depth $=\frac{.60+1.00}{2}=.80$ m
	(L=4.20-.30=3.90 m)						
	Down stream pitching 20 cm depth, excluding toe wall—						
	Bed	1	3.90×	$\frac{4.1+3.2}{2}$	×0.20=	2.85	Sloping breadth at middle
	Side slopes up to ... F.S.L. (Upper length =2.0 m)	2	$\frac{4.2+2.0}{2}$	×1.44	×0.20=	1.79	$=d\sqrt{s^2+1}$ $=8\sqrt{1\frac{1}{2}^2+1}=1.44$ m
					C.O.	68.31	

Item No.	Particulars of items and details of works	No.	Length m	Breadth m	Height or Depth m	Quantity	Explanatory notes
					B.F.	68.31	
	Curved portion ...	2	$\pi \times .6^2$	(area)	×0.20	0.45	Taken as quadrant of
	Top wall ...	2	3.90	0.20	0.30	0.47	sphere.
					Total	69.23	
	Deduct for set back of wing wall ...	2	0.60	0.10	1.15	0.14	
				Net	Total	69.09 cu m	
2	**Cement concrete 1 : 3 : 6** in foundation and floor—Crest wall side walls and floor—						
	(i) ...	1	2.65	6.00	0.45	7.16	
	(ii) ...	1	2.10	5.80	0.35	4.26	
	(iii) ...	1	1.50	5.60	0.25	2.10	
	Wing wall beyond side wall	2	1.80	0.70	0.30	0.76	
	Curtain wall ...	1	4.50	0.60	0.20	0.54	
					Totai	14.82	
	Deduct for set back of wing wall ...	2	0.60	0.10	1.15	0.14	
				Net	Total	14.68 cu m	
	I-class brickwork in 1 : 4 cement mortar—						
	Crest wall—						
	1st step ...	1	4.50	0.70	0.40	1.26	
	2nd step ...	1	4.50	0.60	1.00	2.70	
	Side wall—						
	(i) 1st step ...	2	2.35	0.60	0.40	1.13	}
	2nd step ...	2	2.35	0.50	0.50	1.18	
	3rd step ...	2	2.35	0.40	0.50	0.94	} As per cross sec. BC
	4th step ...	2	2.35	0.30	0.70	0.99	
	(ii) 1st step ...	2	2.10	0.50	0.40	0.84	}
	2nd step ...	2	2.10	0.40	0.50	0.84	} As per cross sec. EF
	3rd step ...	2	2.10	0.30	0.90	1.13	
	(iii) 1st step ...	2	1.50	0.40	0.90	1.08	}
	2nd step ...	2	1.50	0.30	0.60	0.54	} As per cross sec. GH
	3rd step ...						
					C.O.	12.63	

Item No.	Particulars of items and details of works	No.	Length m	Breadth m	Height or Depth m	Quantity	Explanatory notes
					B.F.	12.63	
	Wing wall beyond side wall	2	1.80	0.40	0.40	0.58	As per cross sec. XY
		2	1.90	0.40	0.50	0.76	
		2	2.00	0.40	0.50	0.80	
		2	2.10	0.30	0.70	0.88	
	Curtain wall	1	4.50	0.30	0.40	0.54	
	Toe wall	2	3.90	0.20	0.30	0.47	
					Total	16.66	cu m
4	**Brick-on-edge floor in 1:8** cement mortar including pointing ...	1	5.40	4.50	—	24.30 sq m	Down stream in between walls
5	**Cement pointing in 1** :3 cement mortar— Crest wall (up stream face top and down stream (face)	1	4.50	—	2.40	10.80	Ht.=.6+.6+1.2 =2.40 m
	Side wall inner face (i)...	2	1.80	—	2.00	7.20	
	(ii)...	2	2.10	—	1.70	7.14	
	(iii)...	2	1.50	—	1.40	4.20	
	Side wall portion above crest wall ...	2	0.60	—	0.80	0.96	
	Vertical faces of steppings	2×2	—	0.30	0.30	0.36	
	Vertical face of end	2	—	0.40	0.90	0.72	
		2	—	0.30	0.60	0.36	
	Top of side walls ...	2	6.00	0.30	—	3.60	Full length of 30 cm wall
	Top of curtain wall	1	4.50	0.30	—	1.35	
	Top of toe walls ...	2	3.90	0.20	—	1.56	
	Wing wall top face	2	2.10	0.30	—	1.26	
	Wing wall up-stream side triangular portion above slope ...	2	½(2.10×	1.40)	—	2.94	Triangular portions of slope
					Total	42.45 sq m	

Item No.	Particulars of items and details of works	No.	Length m	Breadth m	Height or Depth m	Quantity	Explanatory notes
6	**Brick-pitching—**						
	Up-stream bed ...	1	1.80	3.60	0.20	1.30	
	Up-stream side slopes	2	1.80	1.62	0.20	1.17	
	Down-stream bed ...	1	3.90×	$\frac{4.1+3.2}{2}$	×0.20=	2.85	Dimensions same as in item 1)
	Down-stream side slopes	2	$\frac{4.2+2.0}{2}$	×1.44	×0.20=	1.79	
	Side curved portions	2	$\pi x.6^2$	(area)	×0.20=	0.45	
					Total	7.56 cu m	

ABSTRACT OF ESTIMATED COST (Ex. 8)

Item No.	Particulars	Quantity	Unit	Rate Rs. P.	Per	Amount Rs. P.
1	Earthwork in excavation ...	69.09	cu m	350.00	% cu m	241.81
2	Cement concrete 1 : 3 : 6 in foundation and floor with stone ballast ...	14.68	cu m	400.00	/ cu m	5872.00
3	I-class brick work in 1 : 4 cement mortar	16.66	cu m	365.00	/ cu m	6080.90
4	Brick-on-edge floor in 1 : 3 cement mortar including pointing ...	24.30	sq m	40.00	/ sq m	972.00
5	Cement pointing 1 : 2 cement mortar ...	42.45	sq m	5.60	/ sq m	237.72
6	Brick pitching (dry) ...	7.56	cu m	120.00	/ cu m	907.20
					Total ...	14311.63
	Add 3% for Contingencies ...				...	429.35
	Add 2% for Workcharged Establishment				...	286.23
					Grand Total	15027.21
					Say Rs....	15027.00

Note :— *In calculating the earthwork in excavation, up-stream bed-level has been considered at G.L. for whole length of the fall. Instead of calculating, earthwork so accurately, it may be calculated approximately.*

ROAD ESTIMATING

EARTHWORK

Cross-section of earthwork of road in banking or in cutting is usually in the form of trapezium, and the quantity of earthwork may be calculated by the following methods :—

Quantity or volume = Sectional area × Length.

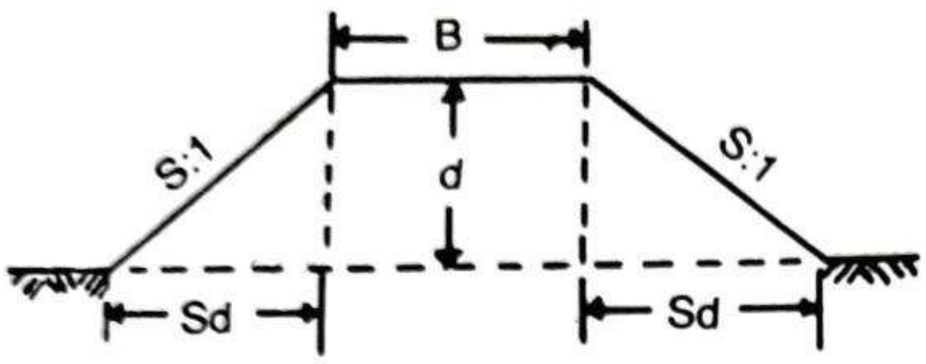


Fig. 7-1
Banking

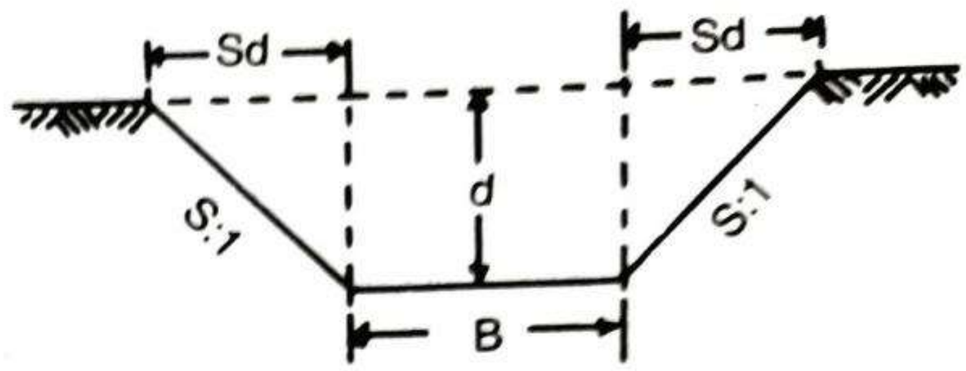


Fig. 7-2
Cutting

Sectional area = Area of central rectangular portion + Area of two-side triangular portions.

$$= Bd+2(\tfrac{1}{2}\, sd\times d) = Bd+sd^2$$

S : 1 is the ratio of side slopes as horizontal : vertical. For 1 vertical, horizontal is s, for d vertical, horizontal is sd.

Quantity= $(Bd+sd^2)\times L$.

When the ground is in a longitudinal slope, the height of bank or the depth of cutting will be different at the two ends of the section, and mean height or depth may be taken for "d" and sectional area at mid-section is taken out for mean height. Alternatively, sectional area at the two ends may be calculated and the mean of two sectional area is taken out. Sectional area at the mid-section or the mean sectional area, multiplied by the length gives the quantity.

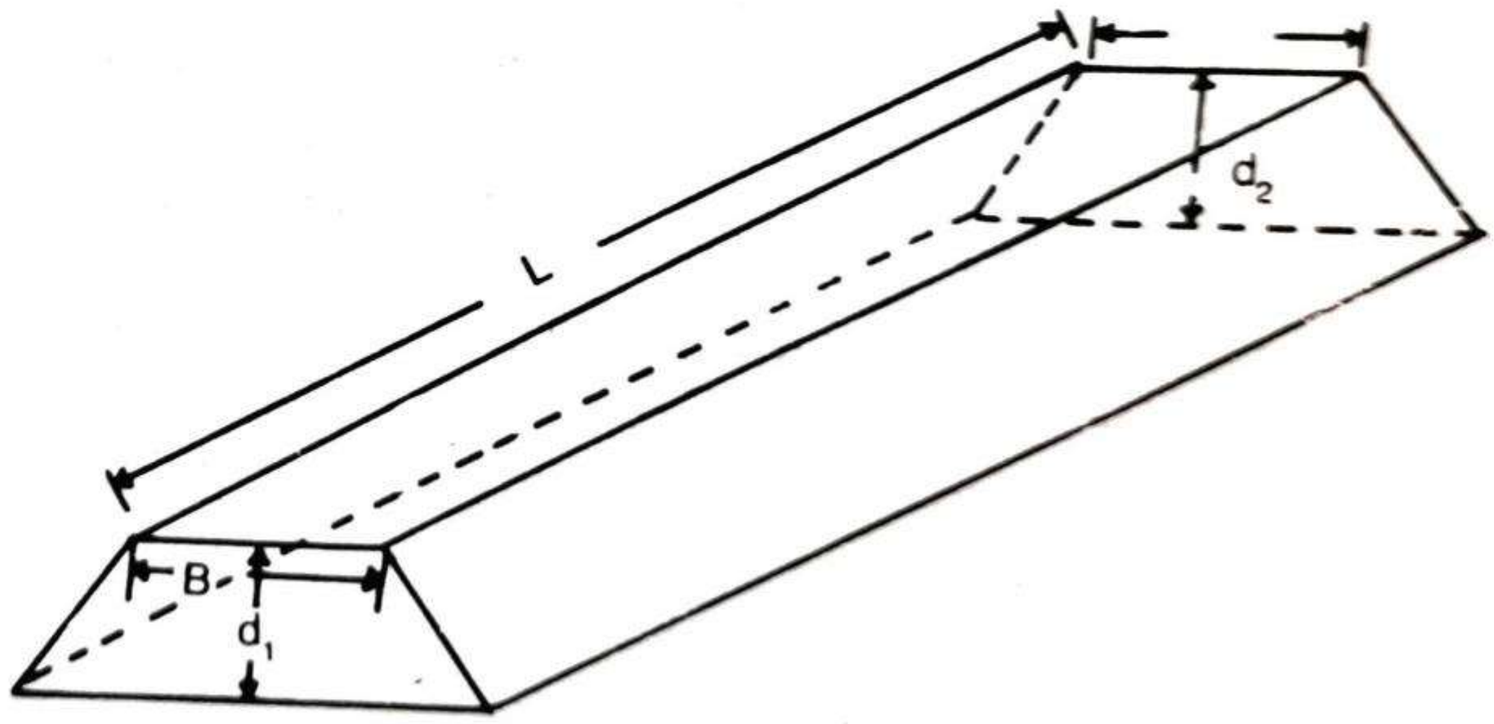


Fig. 7-3

$$\text{Mean height} = \frac{d_1+d_2}{2}$$

Different kinds of soil as sandy, clayey, rocky, etc., estimated separately as the rates vary.

Lead and Lift—Normally earthwork is estimated for 30 m lead for distance and 1.5 m lift for height or depth, and this distance of 30 m and the height of 1.5 m are known as *normal lead and lift.* Normal rate for earthwork is for 30 m lead and 1.5 m lift. For greater lead or lift the rates will be different (higher) for every unit of 30 m lead and for every unit of 1.5 m lift. The earthwork is, therefore, estimated separately for every 30 m lead and for every 1.5 m lift.

Method I. Mid-Sectional Area Method.—Quantity=Area of mid-section×length. Let d_1 and d_2 be the height of bank at two ends portion of embankment, L the length of the section, B the formation width and S : 1 (horizontal : vertical) the side slope then,

Area of mid section = Area of rectangular portion + area of two triangular portion

$= Bd_m + \frac{1}{2}sd_m^2 + \frac{1}{2}sd_m^2 = Bd_m + sd_m^2$

$\therefore$ Quantity of earthwork $= (Bd_m + sd_m^2) \times L$

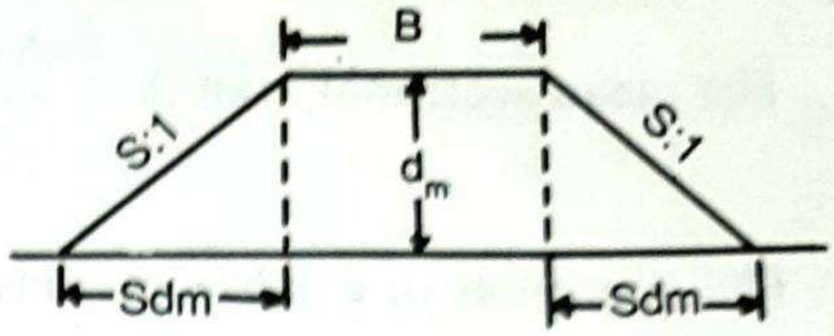


Fig. 7-4

General, $Q = (Bd + sd^2) \times L$, where d stands for mean height or depth.

The quantities of earthwork may be calculated in a tabular form as below :—

Stations or Chain-age	Depth or Height	Mean Depth or Height "d"	Area of central portion Bd	Area of sides Sd^2	Total Sectional Area $Bd+sd^2$	Length between stations L	Quantity $(Bd + sd^2) \times L$	
							Embank-ment	Cutting

Area of side sloping surface —

The area of sides which may require turfing or pitching, may be found by multiplying the mean sloping breadth by the length.

The mean sloping breadth = $\sqrt{(sd^2+d^2)} = \sqrt{5^2+1}$, where d stands for mean d.

Area of both side slopes = 2 L, × d $\sqrt{s^2+1}$

This also may be calculated in a tabular form —

Station or Chain-age	Depth or Height	Mean depth or Height	Breadth of side slopes d $\sqrt{s^2+1}$ *Sloping breadth*	Length between stations L	Total Area of both side slopes 2 L d$\sqrt{s^2+1}$

This table may be added to the previous table or may be worked out separately, d being mean depth or height.

Method II. Mean Sectional Area Method — Quantity = Mean Sectional area × length, Sectional area at one end $A_1 = Bd_1+sd_1^2$, sectional area at the other end $A_2=Bd_2+sd^2_2$, d_1 and d_2 are the heights or depth at the two ends.

The mean sectional area $A = \frac{A_1+A_2}{2}$, Quantity $Q = \frac{A_1+A_2}{2} \times$ Length.

The quantities of earthwork may be calculated in a tabular form as given below :—

Stations or Chainage	Height or Depth "d"	Area of central portion Bd	Area of sides Sd^2	Total Sectional Area $Bd+Sd^2$	Mean Sectional Area	Length between station L	Quantity $(Bd+sd^2) \times L$	
							Emba-nkment	Cutting

Note : *See Example 6 for Method II.*

Method III. Prismoidal Formula Method. — Quantity or volume $= \frac{L}{6}(A_1+A_2+4A_m)$

Where A_1 and A_2 are the cross-sectional areas at the two ends of a portion of embankment of a road of length L, and A_m is the mid-sanctional area.

Let d_1 and d_2 be the heights of banks at the two ends, and d_m be the mean height at the mid-section, B be the formation width and S:1 be the side slope.

Cross-sectional area at one end —

$$A_1 = Bd_1 + Sd_1^2$$

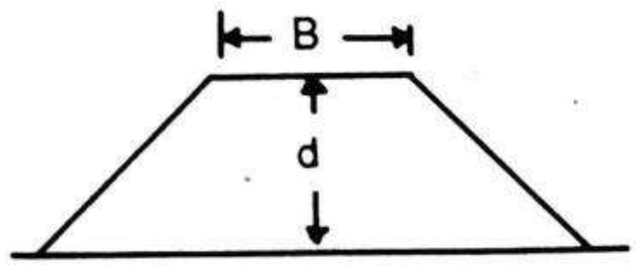


Fig. 7-5

Cross-sectional area at other end —

$$A_2 = Bd_2 + Sd_2^2$$

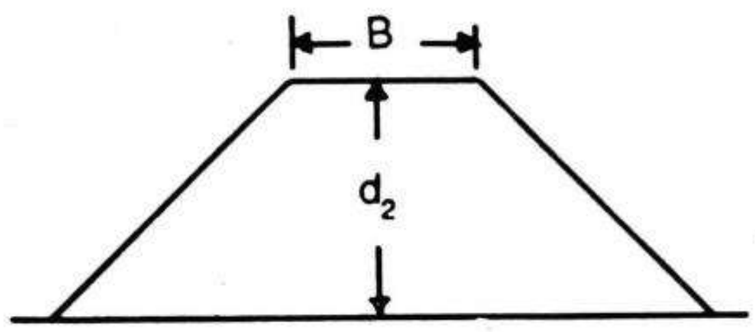


Fig. 7-6

Cross-section at middle —

$$d_m = \frac{d_1 + d_2}{2}$$

$$A_m = Bd_m + Sd_m^2$$

$$= B\left(\frac{d_1+d_2}{2}\right) + S\left(\frac{d_1+d_2}{2}\right)^2$$

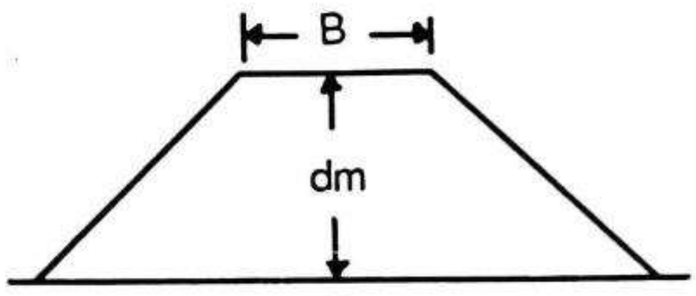


Fig. 7-7

$$\text{Quantity} = \frac{L}{6}(A_1+A_2+4A_m)$$

$$= \frac{L}{6}\left[(Bd_1+sd_1^2) + (Bd_2+sd_2^2) + 4\left\{B\left(\frac{d_1+d_2}{2}\right) + s\left(\frac{d_1+d_2}{2}\right)^2\right\}\right]$$

$$= \frac{L}{6}\left[(Bd_1+Bd_2+4\frac{Bd_1}{2} + 4\frac{Bd_2}{2}) + sd_1^2+sd_2^2+4s\,\frac{d_1^2+d_2^2+2d_1d_2}{4}\right]$$

$$= \frac{L}{6}\left[(3\,Bd_1+3\,Bd_2) + 2sd_1^2 + 2sd_2^2 + 2sd_1d_2\right]$$

$$= \frac{3BL}{6}(d_1+d_2) + \frac{2Ls}{6}(d_1^2 + d_2^2 + d_1d_2)$$

$$= \frac{BL}{2}(d_1+d_2) + \frac{Ls}{3}(d_1^2+d_2^2+d_1d_2)$$

$$= \{\,B\,(\frac{d_1+d_2}{2}) + s\,(\frac{d_1^2+d_2^2+2d_1d_2}{3})\} \times L$$

= [Sec. Area of central portion + Sec. Area of side slope portions] × Length.

The same is also applicable for cutting.

Tabular Form for Prismoidal Formula — The above may be set in a tabular form for calculating the quantity of earthwork for a road. See Example 8, page 345 for tabular form.

Cost of stone pitching = 402.0 × 150.00 Rs.

Example 3.—Reduced level (R.L.) of ground along the centre line of a proposed road from chainage 10 to chianage 20 are given below. The formation level at the 10th chainage is 107 and the road is in downward gradient of 1 in 150 up to the chainage 14 and then the gradient changes to 1 in 100 downward. Formation width of road is 10 metre and side slopes of banking are 2 : 1 (Horizontal : Vertical). Length of the chain is 30 metre.

Draw longitudinal section of the road and a typical cross-section and prepare an estimate of earthwork at the rate of Rs. 275.00% cu m.

(*i*) Find also the area of the side slopes and the cost of turfing the side slopes at the rate of Rs. 60.00% sq. m.

Chainage	10	11	12	13	14	15	16	17	18	19	20
R.L. of ground	105.00	105.60	105.44	105.90	105.42	104.30	105.00	104.10	104.62	104.00	103.3

R.L. of Formation 107.00.

Gradient Down gradient 1 in 150 ——→ ←—— Down gradient 1 in 100 ————————

L=Section and Typical cross-section of the road are as given in Fig. 7-8.

Fig. 7-8

Calculation of Quantities of Earthwork (Ex. 3)

B=10 m, s=2

Stations or Chain-age	Length	Height or Depth *Diff. of G.L. and F.L.*	Mean height or depth d	Central area Bd	Side area sd^2	Total sec. area $Bd+sd^2$	Length in betw. stations L	Quantity $(Bd+sd^2)+L$	
								Banking	Cutting
m	m	m	m	m^2	m^2	m^2	m^2	m^3	m^3
10	300	2.00	—	—	—	—	—	—	—
11	330	1.20	1.60	16.00	5.12	21.12	30	633.6	—
12	360	1.16	1.18	11.80	2.78	14.58	30	437.4	—
13	390	0.50	0.83	8.30	1.38	9.68	30	290.4	
14	420	0.78	0.64	6.40	0.82	7.22	30	216.6	
15	450	1.60	1.19	11.90	2.83	14.73	30	441.9	—
16	480	0.60	1.10	11.00	2.42	13.42	30	402.6	—
17	510	1.20	0.90	9.00	1.62	10.62	30	318.6	—
18	540	0.38	0.79	7.90	1.25	9.15	30	274.5	—
19	570	0.70	0.54	5.40	0.58	5.98	30	179.4	—
20	600	1.10	0.90	9.00	1.62	10.62	30	318.6	—

Total 3513.6 cu m

ABSTRACT OF ESTIMATED COST (Ex. 3)

Item No.	Particulars of items	Quantity	Unit	Rate Rs. P.	Per	Cost Rs. P.
1	Earthwork in banking ...	3513.6	cu m	275.00	% cu m	9662.40
					Total ...	9662.40
					Add 5% (3% for Contingencies and 2% for Workcharged Establishment) ...	483.12
					Grand Total ...	Rs. 10145.52

Example 5.—Prepare a detailed estimate for earthwork for a portion of a road from the following data :—

Dist. in m	0	100	200	300	400	500	600	700	800	900	1000	1100	1200
R.L. of ground	114.50	114.75	115.25	115.20	116.10	116.85	118.00	118.25	118.10	117.80	117.75	117.90	119.50

R.L. of Formation 115 Upward gradient 1 in 200 up to 600 m → ←Downward gradient 1 in 400

Formation width of road is 10 metre side slope 2 : 1 in banking and 1½ : 1 in cutting. Adopt suitable rates.

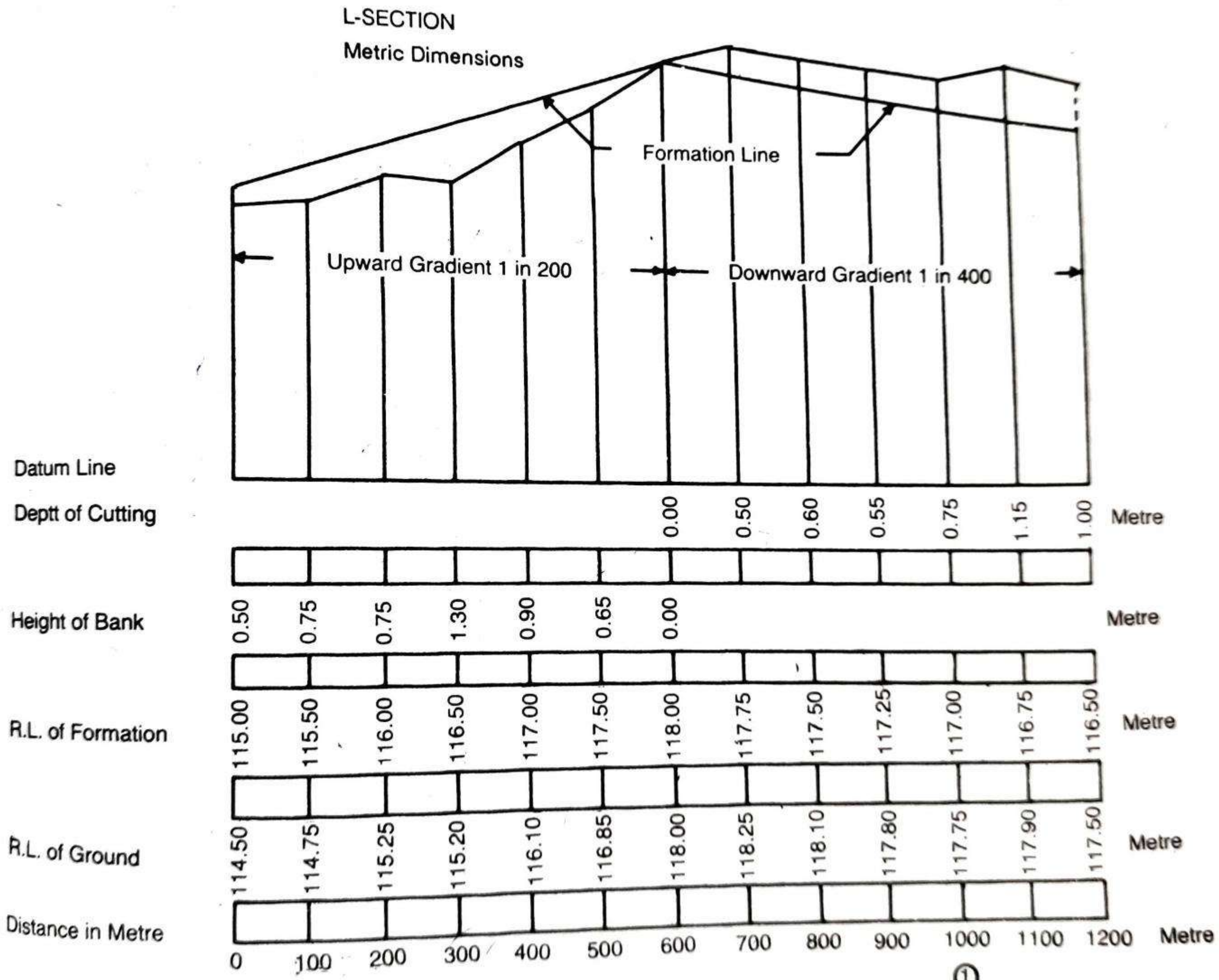


Fig. 7-11

From the data given. L-section can be plotted and heights of bank and depths of cutting of different stations can be calculated. The heights of bank, and depths of cutting are the difference of R.L. of ground, R.L. of formation, and even without plotting L-section the height and depth can be calculated.

ESTIMATE OF EARTHWORK
Calculation of Quantities (Ex. 5)

B = 10 m, s = 2 for banking, and s = 1½ for cutting

Station	Distance *Km m*	Height or Depth *Diff. of G.L.* and F.L.	Mean ht.or Depth d m	Central area Bd m	Area of sides sd^2 m^2	Total sec. area $Bd+sd^2$ m^2	Dist. in betw. stations L m	Quantity $(Bd+sd^2)\times L$ Banking m^3	Cutting m^3
0	0	0.50	—	—	—	—	—	—	—
1	100	0.75	0.625	6.25	0.78	7.03	100	703	—
2	200	0.75	0.750	7.50	1.13	8.63	100	863	
3	300	1.30	1.025	10.25	2.10	12.35	100	1235	—
4	400	0.90	1.100	11.00	2.42	13.42	100	1342	—
5	500	0.65	0.775	7.75	1.20	8.95	100	895	—
6	600	0.00	0.325	3.25	0.21	3.46	100	346	—
7	700	—0.50	0.250	2.50	0.09	2.59	100	—	259
8	800	—0.60	0.550	5.50	0.45	5.95	100	—	595
9	900	—0.55	0.575	5.75	0.50	6.25	100	—	625
10	1—000	—0.75	0.650	6.50	0.63	7.13	100	—	713
11	1—100	—1.15	0.950	9.50	1.35	10.85	100	—	1085
12	1—200	—1.00	1.075	10.75	1.73	12.48	100	—	1248
(—sign indicate cutting)							Total	5384 cu m	4525 cu m

ABSTRACT OF ESTIMATED COST (Ex. 5)

Item No.	Particulars of items	Quantity	Unit	Rate Rs. P	Per	Cost Rs.	Cost P.
1.	Earthwork in banking ...	5384	cu m	275.00	% cu m	14806.00	
2	Earthwork in cutting ...	4525	cu m	350.00	% cu m	15837.50	
					Total ...	30643.50	
					Add 5% (3% for Contingencies and 2% for Workcharged Establishment ...	1532.18	
					Grand Total ...	32175.68	